

Measurements and Calculations of CO₂-Oil Minimum Miscibility Pressure for Omani Crude Oils

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Abstract

In the Sultanate of Oman; there are still large remaining oil reserves that require implementation of the technically more challenging (EOR) applications processes. One EOR method for light oil reservoirs that has proven success in different parts of the world is CO₂ injection.

CO₂ injection could be very beneficial in reducing residual oil saturation levels, for its higher oil ultimate recovery and for its use in the Carbon Capture and Storage (CCS) that leads to desirable benefits on the environment.

Determining CO₂-oil Minimum Miscibility Pressure (MMP) is the key parameter for the design and operations of successful CO₂ miscible flood project. It is worthwhile mentioning that the miscibility with the oil at injection pressure of MMP occurs at CO₂ supercritical conditions, which is the optimum condition to become an efficient solvent.

This research study outlines the method of predicting CO₂-oil MMP for different Omani light oil reservoirs. Pure CO₂ (purity of 99.9%) gas was used for the CO₂ oil Miscibility experiments and it was obtained locally from the Rusail industrial area. The method used in this research study involved two parts; part-1, consisted of the experimental work based on the Rising Bubble Apparatus (RBA) experiments to measure CO₂-oil MMP for different Omani light oils reservoirs and part-2, of the research study contained the development of a mathematical model based on the resulting MMP values obtained from the experimental work in Part-1.

The RBA system was developed and constructed successfully internally in the most cost effective way, at SQU PVT Research Laboratory, with limited resources that required large amount of efforts and engineering thinking.

There is an advantage for the SQU RBA system compared to the existing industry RBA system, is that the thermodynamics behavior required for the CO₂ miscibility in the oil is satisfied due to the fact that there is more mixing of the CO₂ bubble in the oil contained in the larger diameter sapphire cell and thus less surface effects. In addition, the SQU RBA System is less expensive than the market one and the resulting cost saving is 148,400.000 Omani Rials. The built SQU RBA system is the first gas-oil miscibility apparatus in Oman and it provides accurate measurements of gas-oil MMP.

A new design has been discovered during this research study. In spite of the larger diameter of our experimental set-up compared to the commercial RBA system the new set-up allows the visual observation of the CO₂ bubbles rising in the dark crude oil in the sapphire cell. This was achieved at no additional costs or minimal costs.

The SQU RBA CO₂-oil MMP experiments were performed on 11 x Omani oil samples obtained from real oil reservoirs from oil companies in Oman. Successfully achieved CO₂-oil MMP experimental measurements for 10 x Omani oil samples and the results had a range of 5512.50 kPa to 14550.01 kPa. The remaining oil sample due to its poor quality was not possible for the CO₂-oil MMP experimental measurement.

Equation of State (EOS) Phase behavior simulator software PVTPro5.2.1© was used in this research study for the planning and designing of the CO₂-oil MMP experiments. PVTPro5.2.1© gave accurate prediction of CO₂-oil MMP of up to 2.27% difference, for the oil samples compared to the experimental CO₂-oil MMP values, except for one oil sample, the % difference was 28.36. The higher % difference of 28.36 was believed due to the oil sample had its bubble point pressure substantially lower than the initial reservoir pressure compared to the other remaining oil samples.

The mathematical models to predict the CO₂-oil MMP were developed for the Omani light oil reservoirs in this research study. Artificial intelligence (AI) techniques were used for the development of the new mathematical models. These models were derived from the Particle Swarm Optimisation (PSO) and Artificial Neural Network (ANN) mathematical methods. Accurate predictions of CO₂-oil MMP were achieved by using the newly developed PSO and ANN models with % deviation of 5.73 and 2.76 respectively. Therefore, the newly developed PSO and ANN models, in this research study, resulted in more accurate predictions of CO₂-oil MMP for the Omani oil samples than the literature models predictions. It should be noted that the newly developed PSO and ANN models were constructed based on the approach that the literature CO₂-oil MMP data were used for the training process of the models and the RBA experimental CO₂-oil MMP results for the Omani oil samples collected from real oil reservoirs in the Part-1 of the research study were utilised for the testing of models for accurate prediction of the CO₂-oil MMP. This gives an advantage to the newly developed PSO and ANN models that they are general models and they are capable of being applied for Oman light oil reservoirs and more widely.

The newly developed CO₂-oil MMP PSO and ANN mathematical models for the prediction of the CO₂-oil MMP, provide a fast and less time consuming method for the screening of potential Omani light oil reservoirs for CO₂ flooding as an efficient EOR Method.